Compendium of Good Agricultural and Livestock Farming Practices to Minimize Land-Based Water Pollution

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FOREWORD

Dear Reader,

The once abundant water resources of South Asia are getting scarce due to growing population and effects of climate change. Hence, water insecurity is rife in the region. Such scarcity combined with two important factors, namely prevalent water use behavior in agro-practices and the availability of numerous water resources in South Asia which are largely transboundary in nature - has intensified the problem and posed a threat to water quality at a regional scale.

According to the UN Food and Agriculture Organization (FAO, 2016), agriculture in South Asia withdraws 91% of water - well over the global average and much higher compared to other sectors. In addition, agriculture contributes to water quality degradation through various pollutants, namely nutrients such as nitrate, ammonia or phosphate; pesticides; salts; sediments; organic matter; pathogens; metals; drug residue; hormones and feed additives (FAO, 2017). Toxic pesticides, chemical fertilizers and other matter saturate farmlands, leach into ground waters, rivers, lakes and oceans, and spread toxic chemicals. The land and water are then contaminated with harmful toxins, which enter the water we drink and food we eat, resulting in health hazards for human beings and animals. This also has negative impact on livelihoods, the environment, ecosystem, health and well-being.

To dig deeper into the issue of agriculture induced water pollution, the U.S. Department of State and Caritas Switzerland have initiated the regional project "South Asia Environmental Capacity Building - Agricultural and Water Pollution" with country partners in Bangladesh (Caritas Bangladesh), India (DHAN Foundation), Nepal (LI-BIRD) and Sri Lanka (Arthacharya Foundation). The project aims at offering solutions to filling the gap in national policies; strengthening country and regional capacities to identify, acknowledge and address the issue; piloting and testing high-impact solutions; and by establishing a regional multi-stakeholder platform to exchange and disseminate knowledge.

The "Compendium of Good Agricultural and Livestock Farming Practices to Minimize Land-Based Water Pollution" developed by LI-BIRD with contributions from several important resource persons, offers an overview of highly valuable practices for Nepal in line with the project aim. Beyond that, they also support smallholder farmers in becoming more resilient to climate change, and thus securing their livelihoods and bettering their families' lives. Many of the practices developed and implemented in the Nepali context are transferrable to other contexts, and thus offer impactful solutions to tackle water pollution on a regional scale.

On behalf of the project management team, I wish all readers an insightful lecture and successful implementation of the good practices!

Nicola Malacarne
Caritas Switzerland - Project Director
'South Asia Environmental Capacity Building - Agricultural and Water Pollution'

October 2019

FOREWORD

In many countries agriculture is the biggest source of water pollution, and Nepal is not an exception. Water pollution from unsustainable agricultural practices (increased use of chemical fertilizer, pesticides and other form of agro-pollutants) poses a serious risk to environment, natural eco-system/habitat and human health.

There is dearth of information with regards to land use practices and water pollution, as research on agriculture induced water pollution remains in its infancy in Nepal. This report entitled 'Compendium of Good Agricultural and Livestock Farming Practices to Minimize Land-Based Water Pollution' represents an attempt to review and document available indigenous and scientific knowledge/practices on the issue to fill information gaps.

This work was conducted under the project entitled 'South Asia Environmental Capacity Building – Land Based Water Pollution' funded by the US Department of States and Caritas Switzerland, and implemented in Nepal, Bangladesh, India and Sri Lanka by local partner organizations. In Nepal, the project is implemented by Local Initiatives for Biodiversity, Research and Development (LI-BIRD – not for profit, non-governmental organization). The report forms an integral part of project deliverable and an output of an exercise conducted to identify, assess, compile and disseminate evidence-based good practices for mitigating land-based water pollution induced by agriculture and livestock farming practices in Nepal.

Over 30 different good agricultural practices were studied or reviewed, of which, 10 most relevant good agricultural practices are documented in this report. The report is intended for use by agriculture development practitioners, extension workers, policy makers, academia, students and researchers.

Several people contributed in the documentation of evidence based good agricultural and livestock practices presented in this report. On behalf of LI-BIRD, I thank them for their contribution. It is my hope and expectation that this compendium will provide an effective learning experience and referenced resource to a range of stakeholders in planning and implementing future research and development programmes aimed at reducing water pollution induced by poor agriculture and livestock farming practices in Nepal.

Balaram Thapa, PhD
Executive Director

October 2019

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BACKGROUND

Agriculture and livestock farming are among the major causes of water pollution throughout the world and in Nepal. Poor agricultural practices pollute water with excess nutrients like nitrate, ammonia or phosphate; pesticides; salts; sediments; organic matter; pathogens; metals; drug residue; hormones and feed additives (FAO 2017). These can have a multitude of negative impacts on the environment, biodiversity, and human health. So far, few efforts have been made to document and address the relationship between land use and water pollution in Nepal.

This document contains various good practices – developed by farmers, academic institutions, the government, and NGOs – that minimize water pollution from agriculture and livestock farming. Some of the good practices include the use of disease-and pest-resistant varieties, crop rotation, crop diversification, integrated pest management (IPM), biological pest controls, and soil testing, all of which can minimize the haphazard use of agrochemicals like pesticides and fertilizers. The document is designed for use by practitioners and extension specialists interested in adopting or scaling up good practices to address water pollution.

OBJECTIVE OF COMPILATION OF GOOD PRACTICES

The objective of this exercise is to identify, assess, compile and disseminate evidence-based best practices for mitigating land-based water pollution induced by agriculture.

PROCESS OF DOCUMENTING GOOD PRACTICES

This exercise was completed following these steps:

Step 1: A list of various good practices were compiled using secondary literature and expert knowledge.

Step 2: Good practices were prioritized using criteria such as advantage, observability, simplicity, compatibility, and affordability.

Step 3: An experts' workshop was organized to validate the prioritized list of good practices.

Step 4: Experts with experience in the identified good practices each wrote a 4-page flyer on the subject matter.

Step 5: The flyers were reviewed for publication.

GOOD PRACTICES 1

Inetegrated Pest Management:
The Way Forward for Sustainable Agricultural Production

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Secretary
Ministry of Agriculture and Livestock Development

Photo: Santosh Maharjan on Unsplash

ABSTRACT

In recent years, plant protection specialists around the world have shifted emphasis from chemical pesticides to Integrated Pest Management (IPM), which calls for reduced reliance on chemical pesticides. This shift has been propelled by increasing failures of chemical pesticides in controlling crop pests and diseases, and increasing global awareness about pesticides' health and environmental hazards. Once thought to be a panacea for all pest problems, pesticides are today viewed with suspicion and great concern. However, it may not be too late to correct the mistakes and use pesticides judiciously; this is exactly what IPM advocates. Pests and diseases cannot be controlled by relying on any single method - be it chemical, cultural, mechanical, biological, or regulatory. IPM utilizes various methods, combining experience and intelligence. Farmer Field Schools (FFSs), Diversity Field Schools (DFSs), and Plant Health Clinics promote IPM in Nepal. IPM is compatible with Integrated Nutrient Management and is encouraged by the Nepal Good Agriculture Practice (NGAP) standards.

INTRODUCTION

According to Dent (1995), "Integrated Pest Management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintains the pest population below those causing economic injury." IPM emphasizes growing a healthy crop with the least possible disruption to agroecosystems, and encourages natural pest control by empowering farmers. To be successful, IPM requires co-ordination between agronomists, plant breeders, pathologists, entomologists, extension workers, policy makers, and above all, farmers.

IPM can be simplified as follows:

- Use discretion at every stage of agricultural operation.
- Use every plant protection method judiciously.
- Accord highest priority to biological controls and other eco-friendly methods; use chemicals only as a last resort.
- Try to control the pest at every stage of its life cycle.

IPM methods emanate from scientific knowledge about the concerned crop, the bio-ecology of its pests and their natural enemies, and economic and social compulsions. The following methods can be employed in a tiered approach, prioritizing those listed first.

Manage the ecosystem

Many problems can be prevented by growing a healthy crop that can withstand pest attacks, using disease-resistant plants or habitat manipulation. Variety selection is important: a large number of conventional host plants have shown various degrees of tolerance and resistance against a range of diseases and insect pests. Integrated Nutrient Management and cultural practices are also effective means for managing the ecosystem.

Know your foes before taking action

Correctly identifying the pest is key to knowing whether it is likely to become a problem and determining the best management strategy. Regular scouting and participation in Plant Clinics and FFSs are important to correctly identify pests.

Monitor regularly

Routine monitoring of both pests and natural enemies is an important part of IPM. Methods of monitoring include visual inspection, light traps, insect sex pheromone traps, sweep nets, etc.

Establish an action threshold for the pest

It is important to decide whether the pest can be tolerated or whether it is a problem that warrants control. The threshold for action should be based on the pest population level that produces damage equal to the cost of preventing damage by controlling the pest. Plant clinics, pest scouting, and field monitoring are useful in establishing threshold levels.

Use biological controls

Natural enemies – predators, parasitoids, pathogens, and competitors – can be deployed to control pests. In Nepal, common biocontrol agents include: *Trihcoderma*, a wasp that is an insect egg parasitoid; Chrysoperla, a genus of green lacewings that are aphid predators; Metarhizium, a so-called "entomopathogenic" fungus that attacks insects; Beauveria, another entomopathogenic fungus; and *Trihcoderma*, a soil fungus that can protect against other fungal infections.

Use cultural controls

Cultural controls include practices that reduce pest establishment, reproduction, dispersal, and survival. For example, one can change irrigation practices or use crop rotation, mixed cropping, strip farming, or P4 practices.

Use mechanical and physical controls

With these measures, the pest is controlled by luring it into traps, blocking it from entering the cultivation area, or making the environment unsuitable for it. Examples include: insect sex pheromone traps; trap crops like marigolds and chickpeas; poly-houses and agri-nets that serve as mechanical barriers; and mulches and soil solarization that prevent weeds and soil-borne diseases.

Use chemical controls

Pesticides are used only as a last resort and in combination with other control methods. It is essential to follow proper procedures for dose preparation, application, waiting period (safe period), and disposal. In some circumstances, early prophylactic chemical treatment such as seed treatment may be useful to reduce the number of later-season sprays.

Combine management strategies for greater effectiveness

A range of methods can be applied to control pests and diseases in a way that is effective, economical, and has the least impact on non-target species and the environment.

Monitor, evaluate and document the results

Based on the results observed, one can make adjustments to improve the effectiveness of future pest management strategies.

IMPACT

IPM promotes the use of non-chemical methods whenever possible, thereby minimizing the risk of pesticides to human health and the environment. IPM also empowers farmers, agricultural extension staff and concerned stakeholders by educating and engaging them in novel pest management practices. By reducing the use of chemical treatments, IPM reduces negative effects on non-target organisms as well as on land- and water-based ecosystems.

SUSTAINABILITY

IPM requires thoughtful, informed advice and access to some technologies. Expertise must be made available to farmers and their advisors in the extension system. In this regard, a range of trainings suitable for farmers and technical staff can enhance the effectiveness of IPM. Special focus should be placed on biodiversity conservation, pollinators, and pest prevention methods. Synergy can be built by combining IPM with Integrated Nutrient Management and agro-advisory services through Farmer Call Centers, Plant Clinics, and audio-visual kits.

LESSONS LEARNT AND RECOMMENDATIONS

Overall, IPM can help improve air and water quality and enhance biodiversity, especially among pollinators and in soil ecosystems. An improved notification system should be developed for the use of agrochemicals in the country. Opportunities for mass production of bio-rational compounds as alternatives to agrochemicals should be explored. Likewise, it is important to review and document best practices that fit under the IPM framework. IPM has been incorporated into the regulatory frame of the Government of Nepal through the NGAP standards, the Pesticide Act and Regulations, the Food Safety Act, Agriculture Development Strategy, and Five-Year Plans. The federal and provincial governments have accorded priority to IPM in their long-term policies and plans. Hence, IPM seems to be the gateway to a more broadly organic production system in Nepal.

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GOOD PRACTICES 2

Plant Health Clinics: A Novel Approach to Agricultural Extension

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ABSTRACT

Plant health clinics help farmers diagnose pests, diseases, and other problems with their crops through direct interaction with technical experts. Regular plant clinics provide services at fixed locations throughout the country on a fixed schedule – for example, every month – whereas mobile plant clinics travel to different locations without a fixed schedule. Plant health clinics are a novel approach to agriculture extension in Nepal. They focus on all types of crops, promoting IPM solutions for biotic (i.e. pest- and disease-related) and abiotic (i.e. nutrient-related) problems. By promoting the judicious use of agrochemicals, plant clinics can help ensure sustainable management of the agroecosystem, reducing environmental and water pollution. This is especially important as farming in Nepal is shifting towards commercialization, leading farmers to encounter various technical problems. It is necessary to further strengthen the plant clinic program as a component of the plant health system in Nepal.

INTRODUCTION

Development in the agriculture sector has both positive and negative consequences. Commercial agriculture has had negative impacts on ecosystems due to soil and water pollution. Various studies indicate that about 35-40% of pre-and post-harvest losses are caused by pests in Nepal (PPD & FAO, 2004). Thus, timely diagnostic and management strategies to combat yield loss are important. Plant clinics are one approach of agriculture extension for diagnosis and treatment of crop problems, focused on integrated pest management strategies that reduce the deleterious effects of chemical pesticides.

Srivastava (2013) highlighted the importance of plant health security through advisory services like plant health clinics in order to prevent losses occurring from field to fork globally. Plant clinics are a novel extension approach in Nepal, linking stakeholders in the agricultural production system. Regular plant clinics provide services on a fixed schedule, such as every month, to the farmers in a particular location. Mobile plant clinics are run at different locations without any fixed schedule (Adhikari et al., 2016).

According to the Centre for Agriculture and Bioscience International's (CABI's) Plantwise Strategy 2015-2020, a plant health system is defined as "the set of all national plant health stakeholders and their linkages"

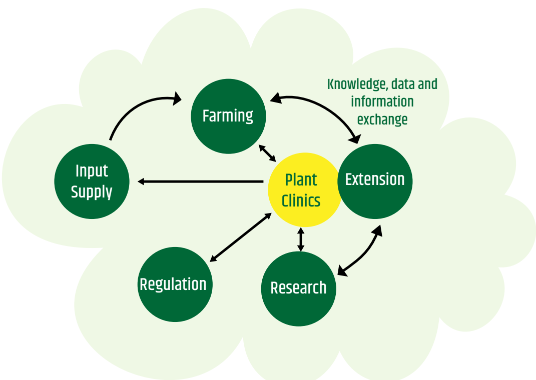

Figure 1: Plant Health System (Plantwise 2015)

(Plantwise, 2015). Figure 1 illustrates how stakeholder linkages are strengthened through plant clinics. Plant clinics play a vital role in facilitating exchange of data and information among the stakeholders of the plant health system in Nepal

METHODOLOGY

Farmers attending plant health clinics present samples of their problematic crops to plant pathologists and other experts. Visual observation of the problematic sample and some relevant tests are conducted to diagnose the cause of plant illness - whether biotic or abiotic – and select an appropriate solution. Plant clinics involve the registration of problematic plant samples, history-taking, examination, and diagnosis. Finally, suggestions and recommendations are provided to the farmers.

IMPACT

Plant clinics' impacts can be observed beyond the immediate effects of diagnostics and advisory services. Plant clinics can be used for training plant protection specialists and extension personnel in field diagnosis of pests and diseases, and they can be used to develop extension materials such as Fact Sheets and Pest Management Decision Guides (PMDGs). The clinics also serve as a means for networking among plant doctors, promoting integrated pest management, monitoring large-scale pest and disease distribution, and alerting the wider farming community about pest outbreaks.

They can create awareness regarding the likely appearance or management of pests and diseases. Plant clinics can be strengthened through the use of the Internet, mobile phones, leaflets, etc. (Adhikari et al., 2017). Similarly, plant clinics' emphasis on IPM and the judicious application of chemical pesticides contributes to the reduction of environmental and water pollution.

SUSTAINABILITY

In Nepal, a pilot plant health clinic was held in December 2008 in Lamjung district by CABI's Global Plant Clinic (GPC) Program (Boa& Harling, 2008). The clinic was popular due to the unique agriculture extension service delivery functions provided and the fact that it was open to all crops and problems encountered by farmers were resolved on the spot. Subsequently, the Government of Nepal through the Ministry of Agricultural Development (MoAD) and the Plant Protection Division (PPD) initiated the CABI-led Plantwise Program in 2011. Moreover, a national forum led by the PPD, MoAD and related stakeholders in the plant health system has been established to guide the future development of plant clinics in Nepal (CABI, 2016). Currently, plant clinics are run by both governmental and non-governmental organizations (Adhikari et al., 2017). Regular trainings on plant clinic modules are provided to agricultural extension workers and plant protection officers. The Government of Nepal has endorsed technical and financial norms to conduct regular and mobile plant clinic programs.

LESSONS LEARNT AND RECOMMENDATIONS

Plant clinics are one of the best tools for extension to farmers because they create a familiar, trust-based environment where farmers and experts can have two-way communications about plant health problems. These clinics have strengthened the plant health system of Nepal, helping to improve plant health advisory services to farmers.

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GOOD PRACTICES 3

Photo: Nick Fewings on Unsplash

Consider and Apply the Saftey Measures While Handeling Pesticides

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Photo: Toya Gautam

ABSTRACT

Chemical pesticides used to control agricultural pests and vectors of disease in the health sector can enter into the body if handlers do not follow proper precautions, causing acute or chronic illness. The health risks of pesticides can be minimized by choosing alternative pest control methods or by applying pesticides safely, using personal protective equipment and harvesting crops only after considering the waiting period.

INTRODUCTION

Agricultural pests include weeds, invertebrates, vertebrates and disease agents or pathogens. Various pests and abiotic factors are responsible for losses in agricultural commodities annually. As discussed in the Good Practice 1 on Integrated Pest Management (IPM), pest management methods include cultural changes, mechanical control, habitat modifications, sanitation, biological controls, and chemical controls.

A pesticide is any naturally derived or synthetic chemical or substance which is used to kill, prevent, destroy, repel, attract, sterilize or reduce the effects of pests such as insects, rodents, fungi, bacteria, viruses, nematodes, and weeds. They vary in their mode of action and may be protectant, sterilant, selective, non-selective, broad-spectrum, contact, systemic, persistent, or nonpersistent in nature, and they are found in different formulations. Pesticides can be divided into inorganic compounds, organic compounds, and natural disease-causing agents.

More than 80% of farmers in Nepal do not wear personal protective equipment like masks, gloves, goggles, hats, and boots. Pesticide exposure during application as well as residues left in food are leading to an increase in the number of asthma, gastro-intestinal, heart, and cancer cases in the population.

Pesticides are usually composed of an active ingredient - a concentrated chemical with a pesticidal character - and an inert ingredient, which serves as a carrier for the active ingredient. The mixture is known as the pesticide formulation. Formulations may come in the form of a liquid, aerosol, emulsifiable concentrate, gas, dust, powder, granules, pellets, or gels. They may be dispersed using sprayers or other equipment.

In Nepal, around 170 pesticides bearing 3,035 trade names have been registered as of December 2018 (PQPMC, 2019). Studies indicate that more than half of farmers consult agro-vets for technical advice regarding pest control, but more than 90% of agro-vets are not technically trained and have not passed the School Leaving Certificate education level.

METHODOLOGY

Pesticide users need to pay close attention to the hazard associated with exposure to pesticides. Pesticides vary

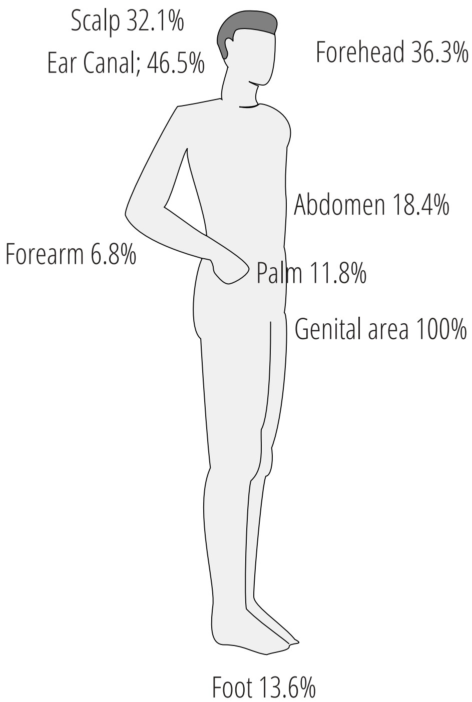

Photo: "hood respirator" by PNASH is licensed under CC BY-NC-SA 2.0

Figure 1: On the left, a study of the herbicide parathion found these percentages of the dose applied were absorbed by the skin over a 24-hour period (Maibach and Feldman, 1974). On the right, personal protective equipment for minimum exposure during pesticide handling.and water pollution.

in their level of toxicity, but the level of exposure is also an important factor in determining hazard. Health hazard is expressed in the equation:

Hazard (Risk) = Toxicity X Exposure

Higher risks are found in handling and applying highly toxic materials, and in mixing and loading pesticide concentrates. Harmful effects from contact or systemic pesticides may be acute or chronic. Acute symptoms include skin irritation, itching, redness, rashes, blisters, and burns. Chronic health effects are birth defects, fertility problems, nervous system disorders, skin disorders, respiratory problems, and cancer.

During handling, mixing, spraying or disposal, pesticides may enter through the skin, eyes, mouth or respiratory tract. Pesticides are likely to enter through the mouth when handlers eat food, drink water, or smoke tobacco while working. Pesticides can enter through the lungs if handlers do not use good respirators. Likewise, pesticides enter through the skin when handlers do not use personal protective equipment, such as the items shown in the diagram below. It is important to use such equipment when opening the cap of the container, pouring, mixing or spraying the pesticide

Studies have shown that about 97% of all exposure to pesticides occurs during the spraying operation, with most of the pesticide entering through the skin (Sherman 2017). Skin in different areas of the body has different absorption rates, as shown in the Figure 1. Hand washing using soap and water can reduce pesticide residue on skin by up to 96% (Curwin et al, 2003). For minimum exposure to pesticides, handlers should follow instructions written on pesticide labels and wear protective equipment while handling, mixing and disposing of pesticides. They should also wash their hands and bathe using soap after finishing the work.

Pesticide poisoning can be a life-or-death matter, so immediate action should be taken whenever it is suspected. The victim should be taken to a hospital without delay. Treatment varies according to the pesticide group, toxicity and exposure in the body. It is therefore essential to consult and follow the advice of a medical doctor.

Before using any pesticide	After using any pesticide
Choose a safe pesticide right for the pest	Dispose of the container properly
Read the pesticide label	Decontaminate the sprayer and other containers used for the pesticide
Use personal protective equipment	Decontaminate personal protective equipment after each shift
Take precautions to reduce exposure during mixing and spraying	Bathe and properly dispose of containers
Inform neighbors before spraying	Put a "pesticide sprayed" notice in the field and wait for the pre-harvest interval to elapse before harvesting

LESSONS LEARNT AND FURTHER RECOMMENDATIONS

To prevent exposure to pesticides during transportation, mixing, spraying, and disposal, workers should wear protective equipment and take precautions to minimize the exposure and entry of pesticides into the body. Pesticides can have many negative effects on human and animal health, including for pollinators, other beneficial insects and microorganisms, fish, and other wildlife. Pesticide use should be avoided except when essential.

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GOOD PRACTICES 4

Integration of Legumes to Increase Diversification and Minimize Water Pollution

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ABSTRACT

Grain-legumes have long been valued because they improve soil quality and provide an important nutritional supplement to the human diet. The spread of chemical-intensive land use systems in which cereal crops are grown on the same land year after year has negatively affected soil quality and crop development throughout the world, also raising concerns about environmental pollution. In this context, there is great scope for the use of restorative legume crop sequences to increase soil organic matter content and improve soil structure. Including pulse crops in a rotation while allowing for accumulation of crop residues can improve the bio-chemical and physical properties of the soil by increasing the labile organic matter. Legume cover crops are also effective at combatting erosion and increasing soil moisture content by decreasing water-induced erosion. Legumes act as a "biological plough" that can increase cropping intensity, land equivalent ratio and land utilization index through sequential crop rotation, intercropping or relay cropping, respectively. Growing legumes in combination with high-tech management practices like high CO2 and foliar fertilization, rhizobium treatments, nodulation (as in rajma beans), nipping, and priming with micro-nutrient solutions can improve the physical, chemical, and biological properties of the soil.

INTRODUCTION

Nepal can be broadly divided into three ecological zones: the Terai plains, the middle hills, and the high hills. Several cereals and grain-legumes have been extensively grown in each zone, from the Terai (150 masl) to Jumla valley (2850 masl), since ancient times. The major grain-legumes of the tropical to warm temperate regions in Nepal are pigeon pea, lentil, chickpea, black gram, cowpea and mung bean. Nepali farmers in warm temperate to cold temperate regions grow soybean, kidney bean, pea and rice beans.

Despite traditionally providing a vital energy supplement to the local diet, legume crops have been planted less and less in Nepal. There is great potential for crop diversification using legumes because of their versatile uses. Integration of suitable winter and summer grain-legumes into existing systems is a viable option for increasing cropping intensity, thereby boosting production and overall productivity, simultaneously improving human and soil health. In the Nepalese hills, increased legume production could help mitigate the problem of food insecurity.

METHODOLOGY

Legume species are uniquely suited for incorporation in cereal and oilseed crop based systems. This type of crop diversification can provide nutrient-rich grains and vegetables for farmers with limited resources. Legumes are suitable for promotion in cropping patterns such as rice-lentil-maize, rice-maize-mungbean, and rice-maize-cowpea. Simple economic analysis indicates that inclusion of legumes in these systems is more lucrative than cereals and oilseeds alone because legumes are of short duration and fit either in the crop sequence or can be intercropped. Therefore, integration of legumes in the systems can enrich soil and be nutritionally and monetarily beneficial to farmers.

Legumes have long been advocated as the "missing ingredient" for conserving soil resources in low-input agriculture, especially in maize-dominated cropping systems in the hills region. They offer high-calorie production with moderate labor inputs, while the absence of a significant legume presence reduces soil nitrogen (N) and recycling of nutrients. Legumes and associated symbiotic organisms replenish soil N and recycle nutrients from deep in the sub-soil. In addition, many legumes have the capacity to excrete root compounds that access phosphorus pools which otherwise remain unavailable. Legumes not only have the capacity to grow in low-fertility environments, they also produce nutrient-rich foods, such as high-protein grain and leaves. The multiple benefits of grain-legumes can be seen in Figure 1.

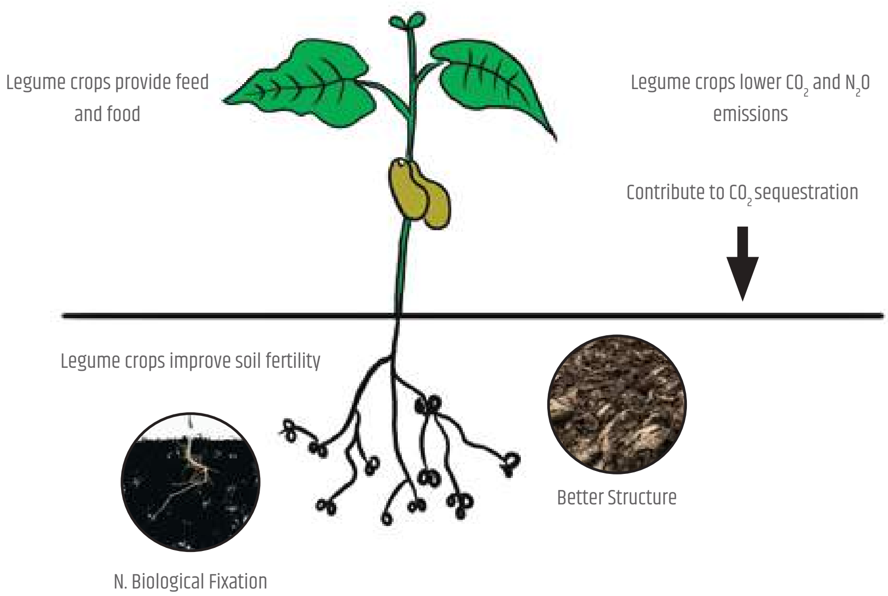

Figure 1. The diverse benefits of grain-legumes in the agricultural production system

IMPACT

Conventional monoculture agricultural systems reduce the quality of soils by causing loss of organic matter and destroying soil structure. The frequent inclusion of pulse crops in a rotation whilst allowing crop residues to accumulate is a proven method to improve the biochemical and physical properties of soil, including increasing labile organic matter. In addition, management practices like crop rotation, tillage, adjustments in planting and harvesting dates, trap crops, sanitation procedures, irrigation scheduling, and fertilization can control a number of plant diseases and pests in legumes. Crop rotation is an important management practice, particularly for developing countries where monocultures threaten the environment.

SUSTAINABILITY

There are many challenges to expanding legume presence in smallholder farming systems. Resource-poor households in Nepal appear willing to grow legumes, but only at low levels. Surveys indicate that labor requirements, seed access, and appropriate genotypes are barriers to legume intensification (NGLRP, 2017). Legumes' biological properties also pose challenges for widespread adoption. For example, legumes' moderate yield (compared to cereals and tubers), initially slow growth habit, and production of relatively few large seeds per plant necessitates the use of large amounts of seed (on a weight basis) per land area, substantially increasing establishment costs. Socio-economic factors also act as barriers to adoption. These include: i) limited and uncertain market access; ii) unstable and highly variable prices for legume products across locations and time; iii) limited farmer access to seeds of improved legume genotypes; and iv) insufficient attention by researchers to the multi-functionality of legumes. Previous on-farm research has shown that resource-poor farmers will not adopt legumes based solely on 'ecosystem service' traits such as soil regeneration. Legume varieties must contain recognizable short-term nutritional and market assets to be of interest to smallholder farmers. This has been debated in the literature, where experimentation with on-farm testing and promoting of green manure and improved fallow legume systems is widespread, but adoption elusive.

To achieve the output of legume integration and promotion, the Outreach Research Division of the Nepal Agricultural Research Council and the National Grain Legume Research Program at Khajura, Banke have initiated various participatory evaluation systems for high-yielding varieties of grain legumes. Identified varieties are tested in farmers' fields and, if successful, are scaled up by mobilizing local extension workers, NGOs/CBOs and farmer groups. The participatory evaluation systems are also focused on high-cost technologies like nutrient loading through priming, rhizobium culture, and advanced cultural practices like CO2 fertilization and nodulation, satellite irrigation and fertigation.

LESSONS LEARNT AND RECOMMENDATIONS

The long-term impact of legumes will be determined largely by the extent and intensity of legume integration into cropping systems, and agronomic practices such as how residues are managed. The slow seed multiplication ratio of legumes and limited market for them reinforce the need for long-term investment in seed multiplication. Continuing support for farmer participatory experimentation is required to enhance local capacity to solve the considerable challenges and document benefits associated with legume diversification in cereal-based systems.

GOOD PRACTICES 5

Photo: Mahesh Shrestha, GrowInnova

Cultivation of Disease- and Insect- Pest- Resistant Crop Varieties: A Way Forward for Reducing Agriculture-Based Water Pollution

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ABSTRACT

Widescale cultivation of disease- and insect pest-resistant crop varieties can significantly reduce the application of agrochemicals, thereby reducing land-based water pollution. Selective breeding for developing disease- and insect- pest- resistant cultivars is the major preoccupation of modern- day plant breeding. For farmers, use of such varieties is the easiest and most cost- effective means to reduce application of agrochemicals in targeted crops while ensuring good yields. A few disease- and pest- resistant crop varieties have been developed and are cultivated in Nepal, but the number is limited and such varieties are not available for a myriad of crops farmers grow. Hence, this good practice will have to be used in conjunction with judicious application of agrochemicals to control disease and pest outbreaks. In the future, crop improvement research must focus on developing more disease- and pest- resistant varieties across crop species. Conservation of crop landraces and their wild relatives must also receive priority in government programs as they comprise a valuable genepool for resistant genes to be used in breeding programs. Finally, efforts are needed to reduce the time lag between the formal release of new crop varieties and widescale adoption by farmers so that maximum benefits can be reaped.

Demonstration plot of potato variety

INTRODUCTION

Crop improvement programs worldwide have primarily focused on yield improvement, disease and pest resistance, abiotic stress tolerance (for drought, flood, salinity, cold, etc.), and quality trait improvements such as nutrition content, cooking time, and taste. Selective breeding for developing disease-and insect- pest-resistant cultivars has been the major preoccupation of modern-day plant breeding. In Nepal, the government-run Nepal Agricultural Research Council (NARC) is the apex research institution mandated to develop farmer-preferred varieties and breeds in a wide range of cereals, pulses, vegetables, oilseeds, forage crops, fruits, and livestock. In addition to NARC, LI-BIRD is one of the few NGOs engaged in crop breeding research to have successfully registered and released crop varieties for commercial cultivation. Box 1 presents two specific cases where breeders have developed insect pest-and disease-resistant crop varieties in Nepal.

Makwanpur-1 is a rice variety released in 1987 for the Terai region where the rice stem borer pest is a major issue. Makwanpur-1 is a coarse-grain, medium-long duration (150 days), stem-borer-resistant, high-yielding (4.3 t/ha) variety popular in the Terai and river basins up to 500 masl.

Pokhareli Jethobudho is a neck-blast-tolerant rice variety developed through selection from the Jethobudho landrace. The variety was released in 2006 for cultivation in and around Pokhara of Kaski district (600-900 masl). It is an aromatic rice with a long growth period (180-185 days) and a yield potential of 2.6 t/ha.

METHODOLOGY

Cultivation of disease- and insect- resistant crop varieties to a large extent depends on how quickly and effectively the agricultural research system is able to generate farmer- preferred varieties and how quickly the extension system is able to disseminate new plant materials. Unlike other good practices included in this compendium, the use of disease- and pest- resistant varieties does not follow a set methodology. Rather, users (farmers) and extension agents (the government, I/NGOs, cooperatives, farmers groups, etc.) will have to keep track of the following in order to promote their application:

- Keep abreast of the latest developments in crop improvement research by NARC and other relevant organizations.
- Closely follow updates from the Seed Quality Control Centre (SQCC) regarding the latest releases and registrations of crop varieties, and breeder and foundation seed balance sheets.
- Access quality seeds of disease- and pest- resistant crop varieties from reliable sources (agro- vets, seed companies, and community seed banks) for cultivation.

IMPACT

Widescale adoption of disease-and insect-pest-resistant crop varieties is by far the easiest and most cost-effective means to reduce the application of agrochemicals while ensuring good yields. This can have a positive impact not only on the health of farmers and consumers, but also on farmers' livelihoods, by allowing them to save on agrochemicals. Finally, the reduction in use - or in some cases the complete elimination- of agrochemicals minimizes agriculture-based water pollution.

SUSTAINABILITY

Farmers can continue growing disease- and insect-pest- resistant crop varieties by using their own saved seeds or by buying quality seeds from the market. There is no additional financial burden associated with the adoption of this good practice. Hence, farmers are likely to realize benefits so long as crop varieties do not lose resistance due to co- evolution of pest biotypes.

For crop varieties to maintain disease- and insect- pest-resistant traits over a long period of time, it is important for farmers to maintain on- farm crop diversity as well as varietal diversity. This effectively delays pathogens' interaction with their hosts, increasing the time it takes for virulent biotypes to evolve. The government and research and extension agencies must convey this message to farmers and refrain from encouraging mono- cropping, which can lead to quicker breakdown of host resistance.

LESSONS LEARNT AND RECOMMENDATIONS

Farmers should utilize available disease-and pest-resistant varieties so far as possible. However, because such varieties do not exist for many crops, farmers will sometimes have to resort to the application of agrochemicals to control diseases and insect pests. In such cases, judicious and safe application of agrochemicals becomes important.

Crop improvement research is a time-and resource-intensive process requiring sustained public- sector funding, which must be guaranteed at the national level. Additionally, conservation of landraces and their wild relatives, which serve as a genepool to draw from for disease- and insect- pest- resistant traits, needs to be prioritized. Finally, there is a need to develop a robust extension mechanism to promote the resistant varieties once they are formally released so that farmers can maximize benefits immediately, with positive impacts on human health and the wider environment.

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Nepal Agricultural Research Council (NARC) and its commodity programs for detail on crop improvement research work. Website: www.narc.gov.np

Seed Quality Control Centre (SQCC) regarding the latest information about release/registered crop varieties. Website: www.scqq.gov.np

GOOD PRACTICES 6

Photo: Eddie Kopp on Unsplash

Soil Testing and Amendment Practices for Balanced Fertilizer Use

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Photo: Roman Synkevych on Unsplash

ABSTRACT

Regular soil testing is an important practice that can inform farmers about the need for fertilizer application and other treatments to bring the soil to optimum productive capacity. Soil testing helps farmers to save on input costs and increase crop yields, and it also has environmental benefits by reducing runoff of excessive nutrients into water bodies.

INTRODUCTION

Soil testing helps farmers determine the exact amount of nutrients available in their soil. Tests can determine the levels of plant macronutrients like nitrogen, phosphorus, and potassium, as well as micronutrients like calcium, magnesium, zinc, and boron, among others. Importantly, soil tests can also determine soil pH and organic matter levels.

The practice of adding a material or a conditioner to the soil based on the soil test result is called soil amendment or amelioration. The added material is supposed to help improve plant growth and health. The type of amendment added depends on the current soil composition, the climate, and the type of crop. Amendments include lime, various types of fertilizers, gypsum, sand, and clay, among other things.

Soil testing is important for all farmers because it is directly connected to crop performance and farm sustainability. Soil tests allow amendments to be tailored precisely to the soil's needs, thus protecting the environment from pollution caused by leaching and runoff of excess fertilizers. At the same time, soil tests improve the nutritional balance of the soil and save farmers money and energy by allowing them to apply only the amount of fertilizer needed.

METHODOLOGY

Farmers should collect soil samples and send them to the lab for testing to detect any deficiencies that could affect crop yields. It is best to perform a soil analysis every 3 or 4 years. Soil sampling and testing methods are as follows:

1. Divide your farm into fields or areas for sampling. If you have areas with different crop growth, soil color, or lime or fertilizer histories, treat each as a separate sampling area. Avoid unusual areas like wet spots, feeding areas, burn piles, or other problem areas.
2. Use a proper sampling tool, such as a sampling tube or auger. If it is necessary to use a shovel or trowel, dig a 15 cm deep V-shaped hole in the soil. Slice a 2-3 cm slab off one side of the hole, and lift out the slab. Cut a middle stripe and keep the soil in a plastic sheet or clean surface.
3. Take soil samples from at least fifteen spots in each sampling area. Mix together all the soils collected within one sampling area. Put about a pint (250-300 g) of the mixed soil in a soil sample bag.
4. Identify each sample by a number. Make a sketch or keep records in a tabular format so that in the future you know which sample came from which sampling area.
5. Take the soil samples to the nearest available soil laboratory. If you do not know where such a facility is available, contact an agriculture technician in your local government unit.
6. Consult agriculture extension staff from your local government unit, Agriculture Knowledge Center, or other non-government agency to interpret the test results and get recommendations.
7. Follow the recommendations!

Though recommendations for soil amendment vary from case to case, some general actions for selected soil test findings are described below.

Sand can be added to clay soil to enhance nutrient mobilization. Conversely, clay can be added to sandy soil to improve water holding capacity. Excessive use of chemical fertilizers can cause toxicity to plants as well as contribute to water pollution. For example, too much nitrogen fertilizer (such as urea or ammonium sulphate) causes an excess supply of ammonium, resulting in

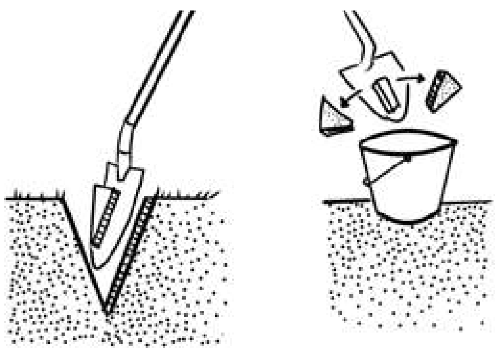

Figure 1: Soil sampling method when using a shovel.

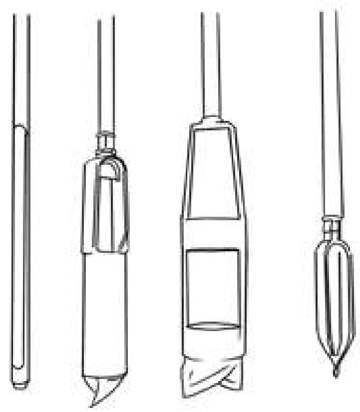

Figure 2: Augurs for use in soil sampling.

Table: Most common findings and suggested amendments in the context of Nepal

S.N.	Findings	Value	Amendment
1	Low pH (acidic soil)	<6	-Apply agricultural lime
2	Low organic matter	<3%	-Increase use of organic fertilizer, manure or compost
3	Low nitrogen	<0.1%	-Integrate legume crops in the system -Use well-decomposed poultry manure -Use nitrogen fertilizers (urea/ammonium sulphate/DAP)
4	Low phosphorous	<20 mg/kg	-Use bone meal (relevant for horticultural crops in a small area) -Use DAP fertilizer -Use well-decomposed poultry manure or compost
5	Low potassium	<50 mg/kg	-Use hardwood ashes -Use murate of potash fertilizer

damage to crops, low yields, and eutrophication in water bodies. Similarly, heavy use of phosphorous fertilizer hampers crop yields because excess phosphate in the soil binds nutrients like iron, manganese, and zinc, preventing their absorption by plants.

Most cereal crops, vegetables, and fruits perform well in soils with medium pH, ranging from 6 to 7.5. At more extreme pH levels, certain nutrients become unavailable to plants even though they are present in the soil. A few crops like apples, grapes, sweet potatoes, potatoes, eggplant, and melon give better or equal yield in slightly acidic conditions (pH 5.5 to 6). Other crops like barley, sunflower, beet, cabbage, broccoli, spinach, and tomato can tolerate slightly alkaline soils.

IMPACT

Soil testing informs farmers about the nutrient condition of their soil, allowing them to appropriately apply fertilizers that contain nutrients like nitrogen, phosphorous, potassium, and calcium. Soil testing also allows farmers to determine micronutrient levels and know whether additions are needed for specific crops – for example, zinc for rice, phosphorous for banana, or boron for cauliflower. Applying too little fertilizer decreases yields, while applying too much increases costs and risks environmental damage due to nutrient runoff. Proper nutrient management through judicious fertilizer use allows farmers to improve crop maturity and quality, increase tolerance to disease and pest damage, and increase growth. Hence, soil testing is a farm management tool with potential benefits for both farmers and the environment.

SUSTAINABILITY, LESSONS LEARNT, AND RECOMMENDATIONS

The Government of Nepal's programs to encourage sustainable soil management and commercial agriculture include facilities like soil camps and subsidized soil testing services. Farmers can access government soil labs at the regional and central level, as well as research stations, local government agricultural extension units, and Agriculture Knowledge Centers. Therefore it is important for farmers to contact and consult about such facilities with the nearest available government agriculture extension workers.

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GOOD PRACTICES 7

Use of Leaf Color Charts for Optimization of Nitrogen Fertilizer Application on Crops

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ABSTRACT

Leaf color charts are an inexpensive and easy tool for monitoring the greenness of plant leaves, which is an indicator of any plant's nitrogen content. The application of the right amount of nitrogen at the right time plays a key role in the proper growth and yield of a crop. Thus, effective use of leaf color charts can help farmers decide when fertilizer application is necessary to maintain proper growth and development, ultimately leading to higher crop yields. Research shows that this site-specific nutrient management practice results in economic and environmental benefits.

INTRODUCTION

Plants require 16 essential elements for proper growth and development. Among them, nitrogen is an essential constituent of proteins. A crop's nitrogen status directly impacts its photosynthetic rate and biomass production. In general, farmers apply urea, di-ammonium phosphate, potash, and farmyard manure as sources of nitrogen, phosphorous and potassium. However, excessive use of such fertilizers can increase the cost of production, resulting in sub-optimal nutrient use by plants, and cause negative effects on the soil, water, and environment. Use of leaf color charts (LCCs) is one among several practices that can optimize the use of fertilizers.

The LCC is an effective and low-cost tool to assess nitrogen status and apply as topdressing when necessary. The LCC is a plastic ruler-shaped strip that contains four to six panels, depending upon the crop, in which the color ranges from yellowish green to dark green. With the help of a LCC, farmers can visually detect nitrogen deficits in their plants. LCCs can be applied to rice, wheat and maize. They are an inexpensive, eco-friendly, and easy-to-use tool that can be used in all regions of Nepal.

The objectives of using a LCC are:

» To apply the required quantity of nutrients at the right time of the crop cycle, as needed.

» To reduce vulnerability of crops to diseases and pests.

» To maximize yields.

METHODOLOGY

LCCs allow easy visual detection of nutrient deficiencies in crops. LCC readings can be taken as follows:

1) Select the plant for testing: Randomly select 10 disease-free plants (rice or wheat) from a field where the plant population is uniform. Select the topmost fully-expanded leaf from the plant.

2) Match the leaf with the chart: Place the middle part of the leaf on the chart and compare the leaf color with the color panels of the LCC.

3) Measure the leaf color: Measure the value on the LCC and note down the reading. The reading should be taken in the shade because direct sunlight can affect the result. If the leaf color falls between two values on the panel, take the average. Separate readings should be taken by the same person to ensure uniformity.

4) Determine the average value: Take the average of the 10 sample plants. For rice, if the average is less than 3, a top dressing is recommended. If it is more than 3, readings should be taken again after 7-10 days. The correct LCC should be used for each crop because the panels are customized for each species.

IMPACT

The use of LCCs can drastically reduce the excessive application of fertilizers in fields. Haphazard chemical fertilizer use can cause nutrients to leach into ground water or wash out on the surface. This pollutes both the land and the water, impacting livelihoods and disturbing the normal functioning of the ecosystem. The excessive use of chemical fertilizers can also make plants prone to disease, and presents an unnecessary expense for farmers. According to research conducted by LI-BIRD under the Climate-Smart Village Project, the productivity of wheat was 2.7 t/ha when LCCs were used, as compared to 2.3 t/ha when they were not.

SUSTAINABILITY

Since LCCs are easy to use and inexpensive, they are effective and sustainable. However, farmers, local institutions and government technicians should be further trained in order to scale up their use.

LESSONS LEARNT AND RECOMMENDATIONS

The use of plastic strip LCCs is an effective, sustainable, low-cost nutrient management practice. LCCs have shown good results in minimizing the haphazard use of urea by encouraging farmers to use the fertilizer effectively and efficiently during the crop cycle. However, local communities, institutions, and government technicians need further training about proper LCC use in order to scale up benefits. In addition, LCCs need to be made easily available in local markets. The government should create policies to promote this good practice and use it more widely in order to better address water pollution.

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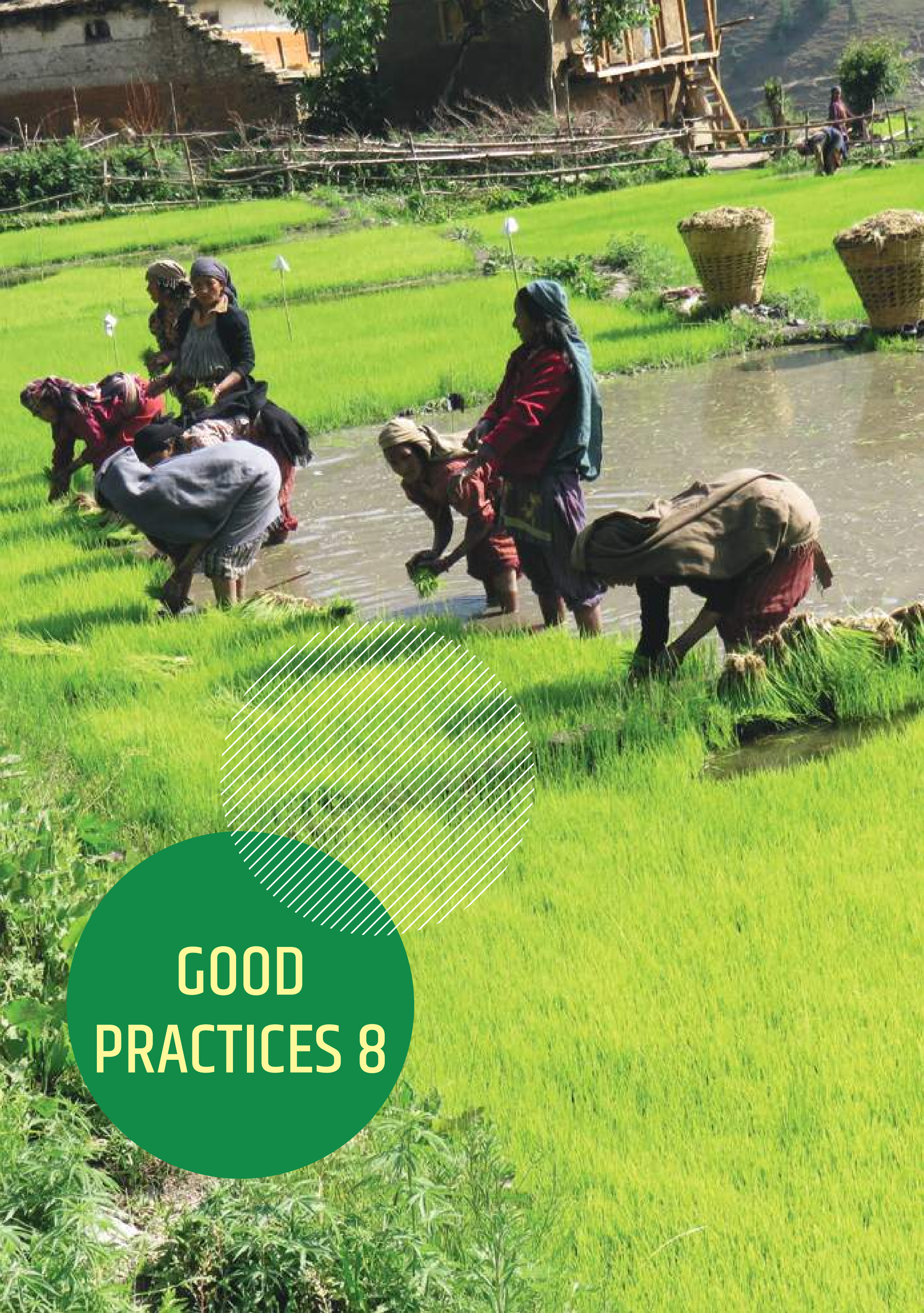

GOOD PRACTICES 8

Integrated Nutrient Management for Augmenting Crop Productivity and Minimizing Soil and Water Pollution

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ABSTRACT

The haphazard use of chemical farming inputs has created serious sustainability problems in Nepal. Integrated Nutrient Management (INM) provides a solution. It requires estimating the indigenous nutrient supplying capacity of a particular soil and supplying only the deficit nutrients at points in the crop cycle when they are most needed, using organics, bio-fertilizers, and chemical fertilizers. INM can improve soil health, crop productivity, profitability, and resource-use efficiency. It can decrease the use of chemical fertilizers, ultimately lowering human and environmental costs while increasing crop yields.

INTRODUCTION

Plants need a balance of 16 essential nutrients and depend on good soil structure for the completion of their life cycle. Generally, non-legumes require a 4:2:1 ratio and legumes require a 1:2:1.5 ratio of nitrogen: phosphorus: potassium, while requirements of secondary and micro-nutrients vary by crop. In most areas of Nepal, intensive rice-wheat, rice-maize, rice-wheat-rice, and rice-wheat-maize cropping systems have severely depleted soil mineral nutrients and destroyed soil structure.

Over-use of chemical fertilizers and underutilization of organic materials has contributed to the problem. The national average for chemical fertilizer use in Nepal has increased dramatically from 16.7 kg ha−1 in 2002 to 67.4 kg ha−1 in 2017; the average use of nitrogen (N), phosphorus (P) and potassium (K) fertilizers in recent years has been 47 kg ha-1, 20 kg ha-1, and 13 kg ha-1, respectively. Meanwhile, farmers use only 2.5 to 3.0 t ha−1 of organic manure annually (NARC, 2013), which is not enough to meet needs. Imbalanced fertilization, soil erosion, and over-use of acid-forming fertilizers compels crops to exploit soil reserves for other nutrients, thereby creating multiple nutrient deficiencies. The high-external-input-based cropping system has also degraded the soil-water system and depleted soil organic matter and carbon stocks.

The future of agricultural production in Nepal is dependent on increased use of mineral as well as organic fertilizers. There is an urgent need for INM for higher yield realization and better soil quality.

METHODOLOGY

INM is based on the principle of managing nutrient inputs to match nutrient deficiencies, synchronizing with the stages of crop growth. The main objectives of INM are: to maintain or enhance soil productivity through balanced use of chemical, organic, and biological sources of plant nutrients; to improve the buffer-stock of plant nutrients in soils; and to improve the efficiency of plant nutrient uptake, thus limiting losses to the environment. INM is comprised of the following key steps:

1. Determine soil nutrient availability and nutrient deficiency in crop plants.
2. Systematically appraise the constraints and opportunities in the current soil fertility management practices.
3. Determine the farming practices and technologies that balance the nutrients which are necessary under different climates and soil types.
4. Assess the productivity and sustainability of INM practices.

INM focuses on optimizing fertilization rates and timing. It incorporates old and modern methods of nutrient management, optimizing all aspects of nutrient cycling with the aim of synchronizing nutrient demand by the crop and its release into the environment (Figure 1).

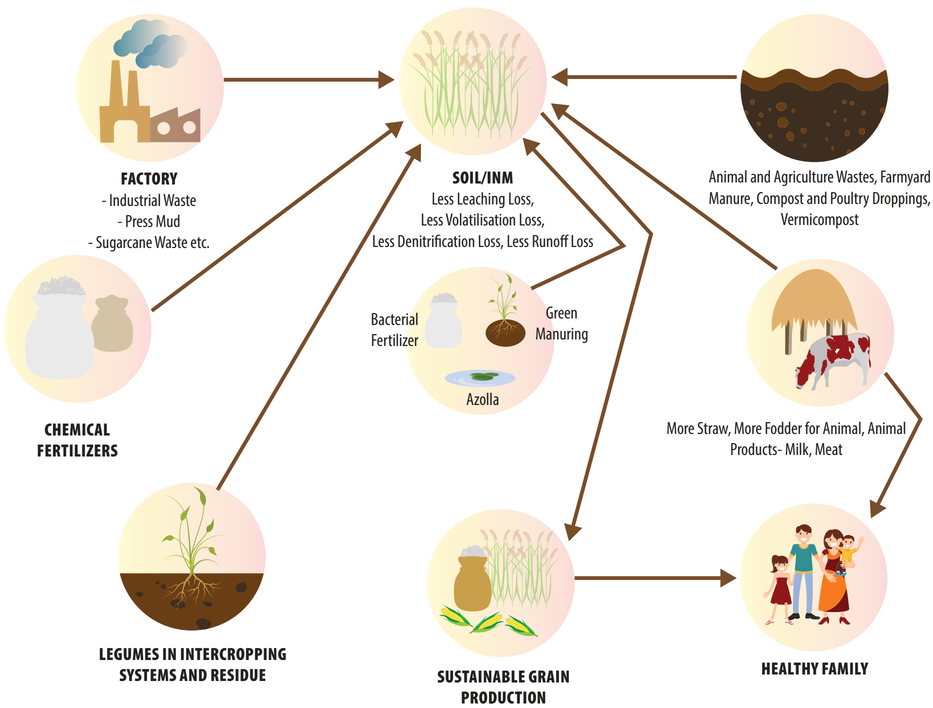

Figure 1. Concept and principles of the Integrated Nutrient Management (INM) system

Infographic: GrowInnova

Specific INM practices include:

- Integrating fertility-restoring crops like green manures, legumes, etc.
- Recycling crop residues.
- Using farmyard manure, compost, vermi-compost, biogas, slurry, poultry manure, biological composts, press-mud cakes, and phospho-compost.
- Utilizing biological agents.
- Using efficient varieties.
- Balanced use of chemical fertilizers as per requirements.

Multi-location trials in rice-wheat and rice-rice systems indicate that green manure crops can supply 50% of the nitrogen requirement of rice, while simultaneously improving soil organic content, nitrogen-potassium-phosphorus status, and soil structure. Deep-rooted grain legumes also have the potential to recycle sub-soil nutrients. Likewise, bio-fertilizers (N-fixing, mineral solubilization, cellulolytic microorganisms) can also reduce the need for chemical fertilizers. Brown manuring, the co-culture of Sesbania and dry seeded rice and knocking down the dicots by applying 2, 4 D ester is a new INM practice that minimizes weed infestation and controls soil erosion, soil mineralization, and the emission of greenhouse gases.

IMPACT

By providing balanced nutrition to crops and improving the physical, chemical and biological functioning of soil, INM is both economically beneficial and environmentally friendly.

A comprehensive review of literature published worldwide revealed that INM increases crop yields by 8-150% as compared with conventional practices. Studies in Nepal's Terai region showed that INM improved farmers' profits by Rs. 1817-8135 per hectare for rice, and by Rs. 1305-5697 per hectare for mustard. Extra profits are due to better soil fertility and reduced inorganic fertilizer input costs.

Excess chemical fertilizer use can lead to groundwater and environmental pollution, and destroy the ozone layer through N2O emissions. By matching inputs and indigenous nutrient supply with crop nutrient requirements, INM minimizes nutrient losses, thereby minimizing damage to soil, water, and ecosystems.

SUSTAINABILITY

The Government of Nepal has long worked to increase the fertility status of cultivable soil through programs of the Directorate of Soil Science under the Department of Agriculture, Regional Soil Testing Laboratories throughout the country, Agriculture Knowledge Centers in each district, Soil Testing Mobile Campaigns, and the Nepal Agricultural Research Council. Likewise, the Institute of Agriculture, other universities, and leading NGOs like HELVETAS, LI-BIRD, SSMP and others have been working towards this goal.

However, INM has not yet been widely adopted in farming communities. Constraints in adoption of INM include: the low nutrient content, slow nutrient availability and bulky nature of organic manures; other competing demand for organic manures; and easy availability and quick recovery of mineral fertilizers. Nonetheless, INM provides a "win–win" opportunity to simultaneously increase crop productivity and improve agricultural sustainability.

LESSONS LEARNT AND FUTURE RECOMMENDATIONS

For each farm, it is important to select specific INM methods after assessing the local resources available and existing practices. The following should be taken into consideration: water management, tillage practices, moisture conservation practices, biotic and abiotic stresses, and the cropping/farming system. Further adaptive research is needed to assess INM with respect to agronomic productivity, ecological compatibility, economic profitability and social acceptability in Nepal; several works are being launched in this line by the Government of Nepal. Furthermore, extension agencies must continue to raise farmers' awareness about deteriorating soil health, unsustainable production, and environmental pollution due to excessive chemical inputs.

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GOOD PRACTICES 9

Use of *Trihcoderma*: A Biological Tool for Crop Disease Management

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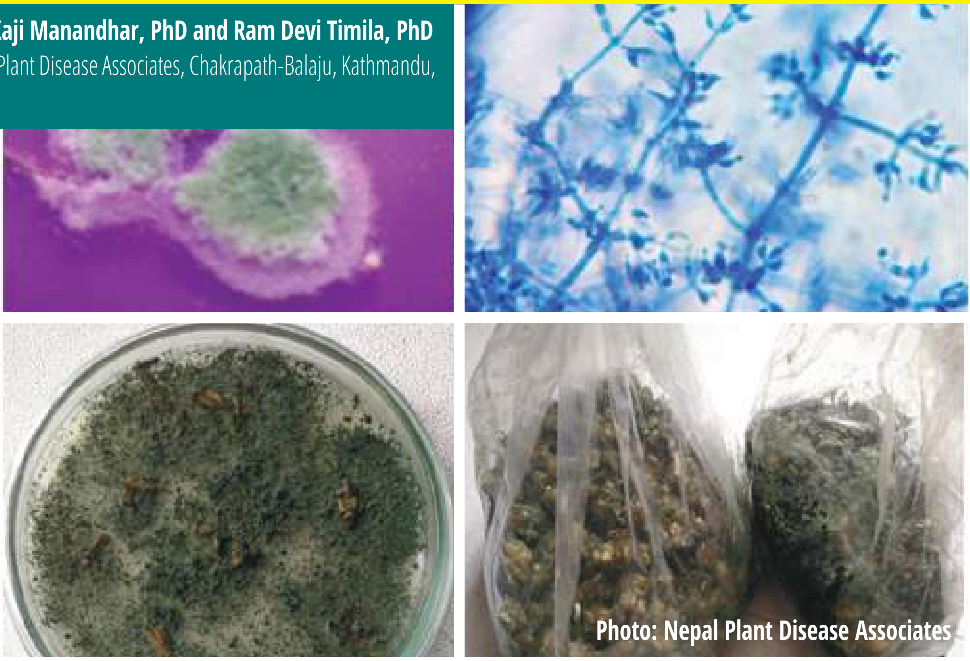
Photo: Nepal Plant Disease Associates

ABSTRACT

Trichoderma spp. are the most extensively-studied and commonly-used biocontrol agents for management of plant diseases. *Trichoderma* are soil-inhabiting fungi that can multiply rapidly. While they can establish themselves in various environments, they are more effective under protected farming conditions (greenhouses) than under open field conditions, and are more effective against soil-borne pathogens than others. *Trichoderma* can be applied by seed treatment, seedling treatment, foliar applications, soil applications, or as bio-fertilizer. They help establish an antagonistic microbial community in the rhizosphere that suppresses pathogens, promotes plant growth, increases nutrient availability and uptake, and enhances host resistance. In Nepal, commercial use of *T. harzianum* and *T. viride* is most common, though other species are utilized as well. Because *Trichoderma* cannot fully control pathogens on their own, their use should be integrated with other measures, including chemical fungicides.

INTRODUCTION:

In 1932, Weindling for the first time reported *Trichoderma lignorum* (now known as *T. viride*) as a parasite of other soil fungi. Since then, *Trichoderma* spp. have been extensively studied and used in management of plant diseases. Generally, *Trichoderma* are reported to be more effective under greenhouse conditions than under field conditions. They need time to adapt in new ecological niches and open fields, where adverse and variable conditions prevail. Because they are soil inhabitants, their use is most effective against soil-borne pathogens such as *Rhizoctonia* (root rot/ damping-off), *Sclerotinia sclerotiorum* (stalk rot/ white rot), *Fusarium* (wilt and root rot), *Sclerotium rolfsii* (collar rot), *Phytophthora* (crown rot/ root rot), and *Plasmodiophora brassicae* (clubroot). *Trichoderma* spp. function through mycoparasitism, hyphal lysis, antibiosis, inactivation of pathogens' enzymes, competition, enhancement of root growth, and induced resistance (Kumar et al., 2017; Ghazanfar et al., 2018; Singh et al., 2018).

Research on *Trichoderma* in Nepal has shown the following: *T. harzianum*, *T. aureoviride* and one native isolate of *Trichoderma* reduced damping-off of radish by 50-80% (PPD, 2001); *T. harzianum* and *T. asperellum* reduced clubroot of cauliflower by 35-40% under field conditions (Timila, 2011); a native isolate of *T. harzianum* (T69) was found as effective as chemical fungicides, copper oxychloride and fluazinam, in managing Phytophthora blight of chilli under field conditions (Timila and Manandhar, 2016); *T. viride* reduced botrytis gray mold of chickpea (Joshi 2001). *Trichoderma* has also been used for better composting (Khadge, 2003).

METHODOLOGY:

Trichoderma spp. are used as a biopesticide and also as a biofertilizer. *Trichoderma* can be multiplied locally in a suitable substrate or bought from commercial producers in powder or liquid forms. They can be applied as seed treatment, seedling treatment (root dipping), soil applications (drenching around the plant) and foliar applications (Cumagun, 2014). *Trichoderma* are used in compost making for fast decomposition; this compost can then serve as both a biocontrol agent and biofertilizer in soils (Kamal et al., 2018).

In Nepal, a number of commercial formulations, especially of *T. harzianum* and *T. viride,* are registered and marketed under various trade names (PRMD, 2017). These include Ecosom-TH, Niprot, and Tricho-HR for *T. harzianum*, and Peak Tricho, Astan-TV, Bhoparistricho, Biocure-F, Biocide Trivi, Carrier, Ecosom, Nicoderma, Nisarga, Sanjevani, Sanjivani, Trichostar, and Tristar for *T. viride*. These can be used as per the instructions given on their labels. A fact sheet on *Trichoderma* use as an anatagonistic fungi in Nepal is available (http://www.idenepal.org/what/Tecnos/IPM_documents/Trichoderma_Factsheet_english_2015.pdf).

IMPACT:

Use of *Trichoderma* as a biocontrol agent can have positive impacts on human health and the environment by reducing or replacing the use of chemical pesticides. The indiscriminate use of chemical pesticides has created a human health hazard, polluting the environment and water sources. In contrast to chemical pesticides, which require repeated use, *Trichoderma* is not a pollutant and, under ideal conditions, may require just one or a few applications due to their self-perpetuating nature.

SUSTAINABILITY:

Use of *Trichoderma* is sustainable for several reasons.

First, they are free-living fungi and can be isolated, evaluated and used locally. Various government and non-government agencies have been supporting production of *Trichoderma* at the local level through centers (previously known as IPM source centers) located in Panauti in Kavre, Topgachhi in Jhapa, Mangalpur in Chitwan, Kopuwa in Kapilvastu, Naubasta in Banke, and Aanbukhaireni in Tanahu (www.youtube.com/watch?v=hbpd3-5b5UU&feature=share). Private companies are also involved in producing *Trichoderma*, such as Agricare Nepal and Phytocare International in Chitwan, and Intensive Multipurpose Agriculture Development Company in Lalitpur.

Second, *Trichoderma* has become increasingly attractive for plant disease management because many hazardous chemical pesticides have been banned. Preference for organic or minimum use of chemical pesticides and fertilizers is increasing gradually.

Third, *Trichoderma* have the ability to reproduce and establish themselves in the soil. This means that the biological control can be kept in place for a much longer time than other methods of pest control.

LESSONS LEARNT AND RECOMMENDATIONS:

While *Trichoderma* can reduce various plant diseases, they may not be a sufficient control on their own. Therefore, *Trichoderma* should be integrated with other compatible management options, including chemical fungicides. Some reports suggest thiram, mancozeb, and copper oxychloride are compatible with *Trichoderma* (Bagwan, 2010; Meena, 2018). Research by the Plant Pathology Division at NARC showed that copper oxychloride (100 ppm) was compatible with *Trichoderma harzianum* (T69) (PPD, 2014).

Farmers should be made aware of several things before using *Trichoderma*. First, *Trichoderma* takes longer to take effect compared to chemical fungicides, so patience is required. Second, *Trichoderma* are living agents that must be alive when applied; their viability is lost during inappropriate transportation or storage. *Trichoderma* should be tested for viability before use if the source is unknown or doubtful. Third, because *Trichoderma* are commonly introduced to new areas from outside sources, it is important to keep in mind that the efficacy of *Trichoderma* is influenced by new environments, including temperature, soil type, moisture, and microbial communities present. To the extent possible, locally-isolated *Trichoderma* should be used as they are the local inhabitants. Fourth, the appropriate dose of *Trichoderma* to be applied depends on the product, its formulation, and the conditions in which it has been stored.

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GOOD PRACTICES 10

Animal Shed Improvement for Sustainable Soil Fertility Management

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ABSTRACT

Organic matter content is an important determinant of soil fertility. Unfortunately, organic content of soils across Nepal is rapidly being depleted. Improved animal sheds can allow for urine collection and protection of animal dung from the sun and excess water. These materials can then be used to replenish soil organic matter. This good practice is easy and popular among farmers. Commercial livestock farms should also be encouraged to establish organic fertilizer and pesticide factories to provide farmers with inputs that can maintain soil fertility over the long term.

INTRODUCTION

Animal sheds are commonly found throughout the Terai, mid hills, and high hills of Nepal. Most farmers let their animals graze freely in pastures and fallow land during the day and bring them back to the shed at night. Unfortunately, little care is given to the health and hygiene of the animals in the sheds. Animal beds are often uneven and stagnant with urine, making animals prone to foot and mouth disease. Leaves and other organic matter from forests are often used as bedding, which mixes with manure and urine. Though farmers apply this to their fields, they often use undecomposed dung and compost, dried animal dung, or the wrong method of application. These practices cause unnecessary loss of plant nutrients and invite harmful insects like white grubs in crop fields.

Table 1. Comparative chart showing annual nitrogen availability from two cows using traditional vs. improved cattle shed management

SN	Particular	Management	
		Traditional (kg)	Improved (kg)
1	Nitrogen available from dung urine and litters	58	58
2	Loses from urine	29.6	6
3	Leaching loses	6	2
4	Volatization loses	14.4	6
5	Available to the plant	6	33.2
6	Collection in the soil	2	10.8

Table 2. Nutrient levels of cow dung kept in roofed vs open compost pits

SN	Particular	Nutrients level		
		Nitrogen %	Phosphorous %	Potash %
1	Pit with roof	3.41	0.42	0.52
2	Pit without roof	2.28	0.36	0.28

As shown in Tables 1 and 2, animal-shed and compost-pit improvement can help conserve plant nutrients contained in manure and urine. Improved livestock shed management can boost crop yields, improve animal health, improve milk hygiene, save farmers money on fertilizers, and reduce pollution caused by excessive chemical use.

Improved livestock sheds are suited to all regions of Nepal, but are best in the mid-hills, the area most vulnerable to soil degradation. The Government of Nepal has been promoting improved composting practices for many years, but momentum was gained in 1998 when it began a pilot program in collaboration with the Swiss government through HELVETAS. The Sustainable Soil Management Project promoted sustainable soil fertility through animal shed improvement, urine collection, and animal dung management. Since 2008/2009, the Government of Nepal has championed improved animal sheds by providing subsidies – starting with NPR 2,000, later increased to NPR 5,200 per shed. Various NGOs working in agriculture, like LI-BIRD, also promote livestock shed improvement.

METHODOLOGY

First, farmers improve the floor of the shed. A cemented floor is prepared to facilitate drainage of urine and dung collection, and to make the shed more comfortable for cattle to sit. Urine is pooled in a collection chamber or tank fed by a gutter, helping to reduce nutrient loses. Along with the shed, a cow dung collection pit is dug nearby, where dung removed from the shed can be kept. It is important to build a roof over the pit to prevent volatilization of nutrients and evaporation of moisture due to sun exposure. The roof also prevents the pit from becoming flooded with water during the rainy season. This environment enhances the decomposition of cow dung.

IMPACT

Improved livestock sheds are popular among farmers throughout the nation. The sheds allow farmers to maximize nutrients from their organic manure supply. The sheds also allow for collection of urine, which was previously underutilized and which can be applied for plant nutrition and preparation of organic pesticides. Livestock shed improvement is thus an excellent way to make better use of the available organic resources and apply them to the soil. The availability of these organic inputs eases the transition to organic agriculture and integrated pest management. Increases in the quantity and quality of organic matter ultimately enriches the soil, making sustainable soil management possible. By reducing reliance on chemical fertilizers and pesticides, improved livestock sheds can help reduce water and environmental pollution.

SUSTAINABILITY

This practice is low-cost, easy, and applicable everywhere. It does not require exotic knowledge or materials, and there are no serious complications in encouraging it. The practice is encouraged at the central level by the Soil Management Directorate and the Ministry of Agriculture and Livestock, as well as by provincial and local-level government units.

LESSON LEARNT AND RECOMMENDATIONS

The value of cow dung has long been known. However, it is often improperly collected, stored, and applied. On the other hand, the practice of collecting urine, which can be used for nutrients as well as for organic pesticide preparation, is very new to the majority of farmers in Nepal. Improved livestock sheds are an excellent way to promote better utilization of both livestock manure and urine.

Improved livestock shed at Majhthana, Kaski

Though livestock populations in farm households have been decreasing, commercial livestock farms are becoming more prevalent across the country. However, they are not giving due priority to urine collection and farmyard manure management, and they are wasting large volumes of organic matter and plant nutrients. Since the government is encouraging the private sector to establish organic fertilizer and pesticide factories, why not encourage commercial livestock farms to do so as well? The government should provide a premium price to producers and more subsidies to farmers for organic fertilizers and pesticides. This will help to reduce reliance on chemical fertilizers, saving money and providing environmental benefits. There is little scope for corruption or misuse of organic fertilizers. Thus, promoting manure and urine use among commercial livestock farms has much potential for retaining soil fertility in a sustainable manner throughout the country.

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